Planetary Instrument Concepts For The Advancement Of Solar System Observations

All-Reflective Spatial Heterodyne Spectroscopy: Extending High Sensitivity Velocity Resolved Measurements of Solar System Dynamics into the EUV

Completed Technology Project (2016 - 2019)

Project Introduction

The EUV spectral region contains ion and neutral transitions that track energetic processes in the solar system at scales from planetary upper atmospheres to the entire heliosphere. EUV signatures are typically associated with transition effects such as shock boundaries, energy deposition sites (aurorae & ionospheres), magnetic field aligned accelerations and gryo-motion (in magnetospheres or the solar corona), plasma pickup processes (e.g. Io plasma torus, comet ion tails, planetary exospheres) and interactions between different particle populations (e.g. resonant charge exchange). A shared characteristic of these processes is that their individual EUV emission features have Doppler signatures that reveal acceleration, multimodal velocity components, and thermal & non-thermal forcing effects that provide unique insight into the underlying processes giving rise to them. The perceived importance of EUV remote sensing of these processes for solar system studies is demonstrated by the frequent presence of imaging and spectroscopic instruments on remote probes (e.g. Voyager, BepiColombo, Cassini, New Horizons) and their inclusion in Earth-orbiting observatories (e.g. HUT, IMAGE, EUVE, SOHO). Unfortunately the existing state of the art in EUV instrumentation is unable to resolve the very Doppler features that contain the most important information in the emission features under study. The lack of a high spectral resolution capability for EUV remote sensing is due primarily to the technical limitations at short wavelengths. Neither transmitting optics nor high efficiency mirror coatings are available in this spectral range. Commonly used broadband materials deliver only modest reflectance (20-50% per surface) that degrades rapidly for wavelengths < 40 nm. Multilayer coatings targeting narrow bandpasses can improve efficiency, but the throughput losses for EUV instruments relative to those at longer wavelengths can still reach several orders of magnitude for multi-element optical systems. When the low surface brightness and broad spatial extent of most observable features in the EUV are factored in, the resulting low throughput of other high-resolution spectroscopic instruments effectively eliminates them as useful tools in this range. The goal of this proposed effort is to address the ‘resolution gap’ in EUV spectroscopy through demonstration of an all-reflective, common-path EUV spatial heterodyne spectrometer (ARCSHS). SHS instruments able to sample a relatively large field of view at high resolving power (R~100,000) and can be made compact enough to fit within the mass and volume limitations of space probes while delivering an etendue 100-1000 times greater than instruments at large telescopes (e.g. HST-STIS). Development of the Spatial Heterodyne Extreme Ultra-Violet Interferometer (SHEUVI) will be a first for both high spectral resolving power and interference spectroscopy at lambda <90 nm. Astronomical interferometry has not been attempted the EUV, because the optical surface quality and mechanical accuracy requirements of most common astrophysical implementations have been, and remain beyond practical reach. Both theory and testing have shown the interferometric performance of ARCSHS alleviated key surface quality

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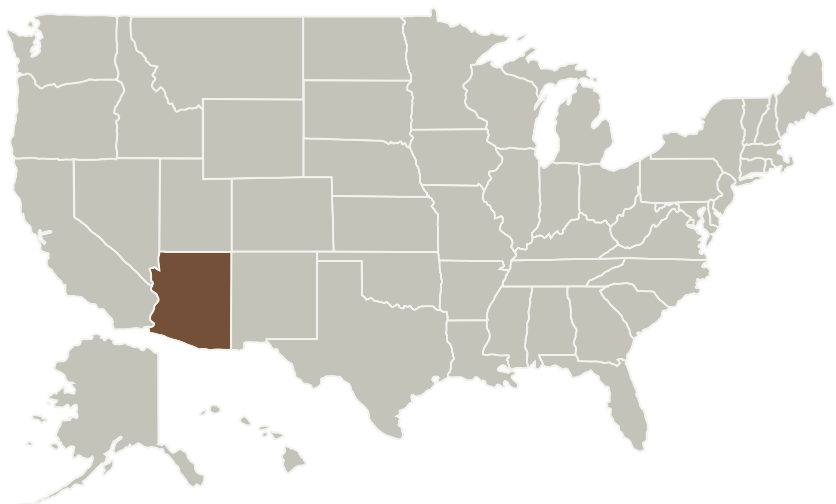
limitations common in other FTS designs. The common optical path of the instrument also enhances its stability against mechanical and thermal shift. Additional advances in coarse ruling, high-order gratings have eliminated previous issues that prevented ARCSHS designs intended to cover multiple pass bands simultaneously. Finally, advancements in optical fabrication techniques targeting industrial applications have improved optical surface quality, diffraction grating efficiency, and multilayer coating reflectance across the EUV spectral range. These factors combine to provide a very credible path toward the development of SHS at wavelengths into the EUV.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Arizona	Supporting Organization	Academia Alaska Native and Native Hawaiian Serving Institutions (ANNH), Hispanic Serving Institutions (HSI)	Tucson, Arizona

Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Responsible Program:

Planetary Instrument Concepts for the Advancement of Solar System Observations

Project Management

Program Director:

Carolyn R Mercer

Program Manager:

Haris Riris

Principal Investigator:

Jason B Corliss

Co-Investigators:

Mary Gerrow
Walter M Harris
Bill R Sandel

Primary U.S. Work Locations
Arizona

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **4**

1 2 3 4 5 6 7 8 9

Applied Research | Development | Demo & Test

Technology Areas

Primary:

- TX08 Sensors and Instruments
  - └ TX08.1 Remote Sensing Instruments/Sensors
    - └ TX08.1.5 Lasers

Target Destination

Others Inside the Solar System